Performance based design of structures based on seismic damage control for structures with special steel moment frame

Ali Hoseini-Rad

alihoseinirad1872@gmail.com

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Department of Civil Engineering
Isfahan University of Technology, Isfahan 84156-83111, Iran

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Supervisor: Dr. Farhad Behnamfar, Farhad@cc.iut.ac.ir

Abstract

Generally, seismic design of structures can be conducted through disparate methods including code-based method and performance-based ones. The performance-based design (PBD) methods are directly (e.g. damage controlled seismic design method (DCD)) or indirectly (e.g. displacement-based design (DBD)) pertinent to the damage concept. As for the seismic design of structures using the force-based design (FBD), well-known as a simple and time-saving method, the earthquake phenomena is taken into account equivalent to horizontal static load. Through the using of PBD methods (including DBD and DCD) and defining new levels of performance, a novel framework will be introduced within the field of structures' seismic design. Considering the DBD method, a maximum drift with regard to structure's level of performance is taken into account and then the structure would be substituted with a single degree of freedom system (SDOF). Afterwards, the structure will be designed using the base shear calculated with the equivalent stiffness and damping. More to DCD method, it is feasible to design the structure on the basis of global and local damage index, by which the structure's damage level would not exceed the considered limit.

Throughout this study, a new method named as damage controlled seismic design has been developed and elaborated in details. Through the usage of this method, in the first place, modified Park and Ang damage index, which is based upon the relation of deformation and energy, has been transformed into a drift-based damage index using regression and several analysis. Having an appropriate drift determined from the damage index, its base shear will be calculated in the considered level of performance. In this study, firstly the 4-8-12-storey structures respectively representing low-rise, medium-rise and relatively high-rise buildings within the zone of soil type D, are designed in ETABS software in accordance with ASCE 7-16 code. Thereafter these structures are modelled in OpenSees software by the exploitation of concentrated plasticity method to perform non-linear dynamic analysis. By the end of design process using disparate earthquake accelerogram and repeating non-linear dynamic analysis in OpenSees, it has been concluded that the damage index would remain within the considered level of performance. In addition, the proposed method provides a deep understanding of structure's non-linear behavior in the course of earthquake.

More to present study, a comparison has been drawn between DCD and FBD methods, by which it has been inferred that for DCD method, the base shear force in 4, 8 and 12 storey buildings are respectively 8.95%, 6.11% and 6.03% less than FBD method and provide softer structures with higher periods. It should be highlighted that these given values are pertinent to damage index of 0.4 and in case of lower damage index, the base shear force is increased and thereby the structure would be designed heavier. To make this distinction clearer, having the structures designed with 0.2 damage index, a comparison has been made between the damage index results of 0.2 and 0.4. The drawn comparison reveals that the base shear forces of damage index 0.2 for 4, 8 and 12 storey buildings are respectively 23.2%, 15.65% and 16.55% more than damage index 0.4. By an increase in the base shear force values, the structural elements and structure's stiffness are enlarged and consequently the maximum inter-storey drift is diminished.

Keywords: Damage controlled seismic design, Park and Ang damage index, Drift, non-linear dynamic analysis, steel moment-frame